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Prototype of IoT-based Clothes Drying Control System using Infrared Thermometer MLX90614

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ABSTRACT

The recent climate change has caused instability in seasonal transitions, consequently complicating weather predictions especially in rainy seasons. This situation presents several challenges, particularly in the context of outdoor clothes drying, especially when the house is left empty or there is no one inside. Moreover, public clothes washers use the same place for different types of clothes and use chemicals that often damage clothes. This can be prevented by washing at home. Hence, there is a need for automated clothes drying device when rain detected. Our prototype utilizes a raindrop sensor, infrared thermometer MLX90614, and implements the Internet of Things (IoT) that employs a telegram bot for monitoring and control, thus enabling the avoidance of weather instability effects on clothes drying, ensuring clothes are dried automatically when it's not raining. Functional software testing results indicate the device operates effectively, though in hardware there are still issues with the stability of motor movement, which will be addressed in further research stemming from this article.

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1. INTRODUCTION

A clothesline is a simple device used for drying clothes outdoors. It typically consists of a rope or wire stretched between two points, such as poles or hooks, where wet laundry can be hung to air dry. Clotheslines are commonly used in residential settings, especially in areas where dryers are not readily available or to save energy costs by avoiding the use of electric or gas-powered dryers. They come in various forms, including traditional T-pole clotheslines, retractable clotheslines, and umbrella-style clotheslines [1]. Clotheslines offer an environmentally friendly and cost-effective method for drying clothes, utilizing natural sunlight and airflow to dry garments. The recent climate change has caused instability in seasonal transitions, consequently complicating weather predictions. This situation presents several challenges, particularly in the context of outdoor clothes drying [2]. Although air drying of clothes outdoors is considered an economical option as it does not require special equipment, this method has its drawbacks, especially when rain suddenly arrives without any supervision to move the clothes affected by the rain.

In order to address these challenges, the implementation of the Internet of Things (IoT) in clothes drying management has emerged as an innovative solution. IoT refers to a network of interconnected physical devices that can communicate over the internet [3][4]. In this context, the implementation of IoT in clothes drying aims to provide better supervision and control over the drying process. In an IoT system for clothes drying management, integrated sensors on the clothesline and garments function to detect weather and environmental conditions. Information obtained from these sensors is transmitted to a platform or application accessible to users via mobile devices or computers. With this capability, users can monitor the status of clothes drying in real-time and receive immediate notifications if there are weather changes that could affect the drying quality. One of the main components in this IoT system is the smart clothesline. Equipped with an automatic mechanism, this clothesline can move clothes indoors if the weather worsens or rain suddenly arrives. Weather sensors installed on the clothesline can detect humidity and rainfall, enabling the clothesline to make decisions based on environmental conditions [5]. The clothes being dried can also be equipped with humidity sensors that send data to the IoT platform. This helps prevent excessive humidity that can damage clothes, such as mold growth or unpleasant odors. This IoT system can be integrated with other smart devices in the home, such as virtual assistants or automated settings. For example, users can schedule clothes drying times according to their schedule or preferences, enhancing efficiency and convenience in clothesline management [6][7]. The advantages of using an IoT system in clothesline management include time and energy efficiency, as well as in various other fields [8][9][10]. Users no longer need to repeatedly lift and lower clothes when the weather changes or to avoid rain. Furthermore, better supervision of the drying process helps maintain clothing quality more effectively, avoiding potential damage due to prolonged exposure to sunlight or excessive humidity. In the face of uncertain weather conditions, the use of IoT technology is crucial in providing convenience and efficiency in clothesline management. This system is designed to provide comfort for users, whether they are outside the home or in other situations. Thus, all clothes on the clothesline can be protected from rainwater, and users no longer need to repeatedly perform the task of lifting and lowering the clothesline.

2. METHODS

For this research, we adopt the waterfall method, the waterfall method is a traditional software development model that follows a linear and sequential approach. In this method,

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each phase of the software development life cycle (SDLC) is completed sequentially, with the output of one phase serving as the input for the next phase [11][12]. The phases typically include requirements gathering, system design, implementation (coding), testing, deployment, and maintenance. The waterfall method is a sequential development approach, following structured stages like a waterfall. This model involves requirements analysis, design, coding, testing, implementation, and program maintenance [13][14][15]. Although considered to have significant risks and higher costs due to meticulous replanning, this method tends to produce accurate and detailed research, as shown in **Figure 1**.

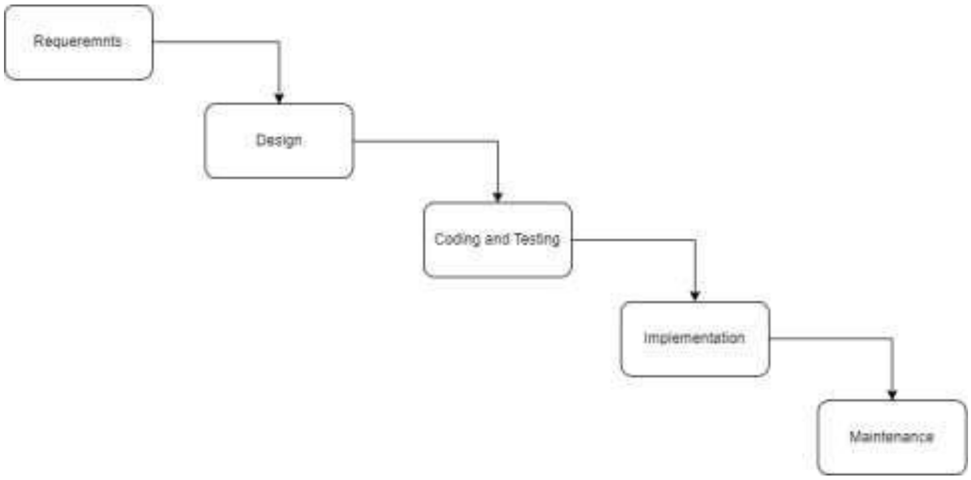

Figure 1. Block diagram of waterfall method

In **Figure 1**, there are five stages in creating the system, starting from requirements analysis to implementation and maintenance. The requirements analysis stage involves selecting IoT hardware, development software, and weather data to be processed. In the design stage, requirements are translated into blueprint designs to facilitate the coding and testing process. The coding and testing stage involve implementing the design into a tangible system. Functional testing is conducted using black box testing techniques to ensure the system can read and interpret weather data. The fifth stage involves implementing the system to protect the clothesline from rain automatically. Finally, the maintenance stage is necessary for system upkeep and development over time [16]. Although the waterfall method is rarely followed strictly due to evolving software specifications and versions, as well as a lack of user feature requirement information, it remains the foundation for structured system development.

2.1. Hardware Configuration

The hardware configuration for the prototype of IoT-based clothes drying control system includes a microcontroller or development board such as Arduino or Raspberry Pi, the Arduino UNO is a microcontroller board utilizing the ATmega328P. Featuring a 16MHz ceramic resonator, a power jack, USB connectivity, a reset button, and an ICSP header, it offers 14 digital input/output pins (with 6 configurable as PWM outputs) and 6 analog inputs [17][18]. This versatile board is capable of self-sustained operation, allowing power from either a battery or an AC-to-DC adapter. In addition, various sensors like raindrop sensors for detecting rainfall and temperature sensors for measuring ambient and object temperature, actuators such as DC motors for moving the clothesline and fans for drying clothes, communication modules like Wi-Fi or Bluetooth modules for connectivity, a power supply which could be batteries or a dedicated power source, and additional components like breadboards, resistors, and capacitors for circuit connections as shown in **Figure 2**.

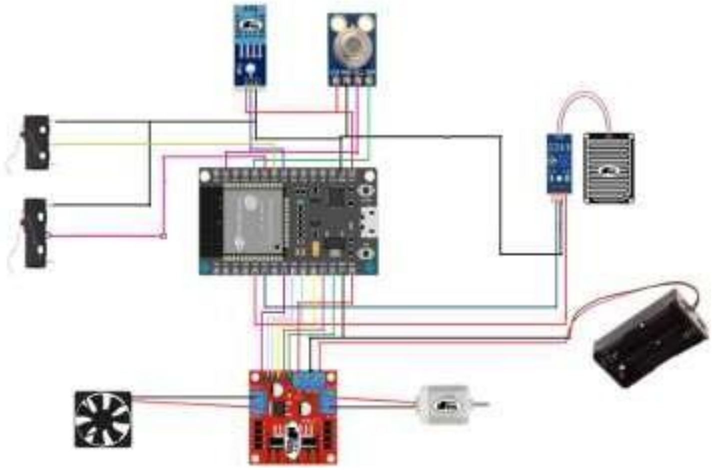

Figure 2. Wiring diagram of proposed device

Based on the wiring diagram in Fig.2, the device comprises several components: a Raindrop Sensor for detecting rainwater, an ESP32 for controlling the system, an L298N Driver to activate and regulate the DC motor, a DC Motor for moving the clothesline rope, a Fan for clothes drying, a Battery Socket for power supply, an MLX90614 Sensor for detecting object temperature (clothesline), a DHT11 Sensor for humidity detection, and a Micro Switch for manual clothesline rope movement triggering. After the wiring diagram is explained, we refer to a broader overview, namely the system architecture as shown in **Figure 3**.

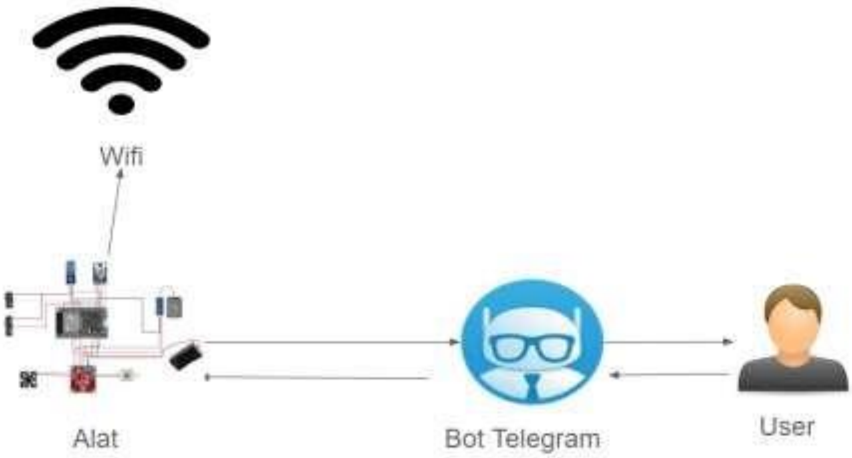

Figure 3. Proposed architecture.

In Fig. 3, we use telegram bot, additionally, an internet-connected device, such as a smartphone or computer, is required for receiving and ending messages to the IoT platform, typically using services like Telegram for control and monitoring purposes as done also by [19][20].

3. RESULTS AND DISCUSSION

We created miniature automatic clothes drying device using wood materials assembled in a specific manner and combined with the hardware components mentioned above. For the clothesline, we used strong thread to attach miniature paper clothes, which served as the objects to be dried. In this manufacturing stage, we primarily focused on developing the prototype first, which we will further refine. Consequently, we acknowledge certain

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weaknesses, yet testing on this system has demonstrated its success with minimal requirements. Test results include hardware and software testing at a functional scale only; reliability testing will be conducted on a full-scale device. The results of our prototype device are illustrated in **Figure 4**. Prototype Device.

Figure 4. Prototype device

3.1. Functionality Testing

Hardware testing is conducted to assess the functionality and performance of each component used. The testing involves evaluating the system's performance, determining whether the sensors can effectively detect rainfall, and testing the overall functionality of the device to ensure it operates properly.

Table 1. Hardware testing.

Sensor	Expected Result	Test Result	Explanation
Raindrop	The Raindrop Sensor is tested by simulating rainfall, typically by wetting the sensor with water. When the sensor detects water, it triggers the DC motor to rotate, indicating that it can effectively detect rainy conditions.	The sensor is able to detect water on its surface, and the DC motor rotates accordingly.	Detected
DHT11	The sensor can detect ambient humidity.	The sensor successfully obtains ambient humidity data	Detected
MLX90614	The sensor can detect the temperature of objects within a radius of 10-15cm. If the temperature of the object (clothesline) is below 28°C, the fan will turn on, and if it is above 28°C, the fan will not turn on.	The sensor can recognize the temperature of the object (clothesline) as well as temperature variations. If the object's temperature is below 28°C, the fan turns on, and if it is above 28°C, the fan turns off.	Detected

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3.2. Software Testing

Software testing is a process that determines whether the functions of the commands created in the Telegram bot work effectively in monitoring and controlling the clothesline device as shown in **Figure 5**.

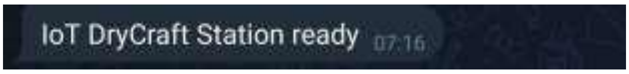

Figure 5. Bot telegram that states IoT device ready

The image above shows the display of messages from the Telegram bot when the device is connected to the internet and ready to operate. After that, we tested the scenario if rainwater is detected and the Telegram bot displays as shown in **Figure 6**.

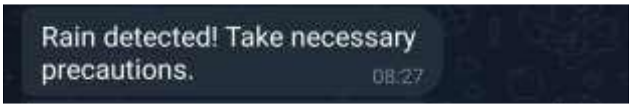

Figure 6. Bot telegram that detects rain condition

In **Figure 6**, after the condition indicates rainfall, we proceeded to test the temperature and humidity sensors as well as the DC motor to verify if they work and provide notifications on the Telegram bot, with the test results shown in **Figure 7**.

Figure 7. Commands in bot telegram for controlling and monitoring device

The image above depicts monitoring and controlling commands, along with system responses for the designed device, featuring functions such as /temp for ambient temperature monitoring, /humidity for humidity monitoring, /tempobject for object temperature monitoring (clothesline), and /tarik for controlling the DC motor to pull the clothesline indoors.

4. CONCLUSION

Based on the conducted research, it was found that the design of the prototype of iot-based clothes drying control system automated clothesline device functions well. This automation device can detect rainy conditions and automatically move the clothesline indoors when rain is detected. Additionally, the device can activate the drying fan

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automatically when the object detected within the sensor's range is below 28°C. Finally, the implemented monitoring and controlling functions in the Telegram bot also work well. The designed bot will automatically send messages when the device is in certain conditions, and the monitoring function works effectively, with the bot delivering requested information accurately and promptly. Meanwhile, the waterfall method has its advantages in terms of clarity and structure, it also has drawbacks, such as limited flexibility to accommodate changing requirements and the potential for late-stage errors to be costly to rectify, therefore, for future research, we aim to address this issue and the stability of the motor in rotating the clothesline rope outward and inward.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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